Shortlist Masterplan Wind. Evaluation of the sampling grid of the year-round ichthyoplankton survey

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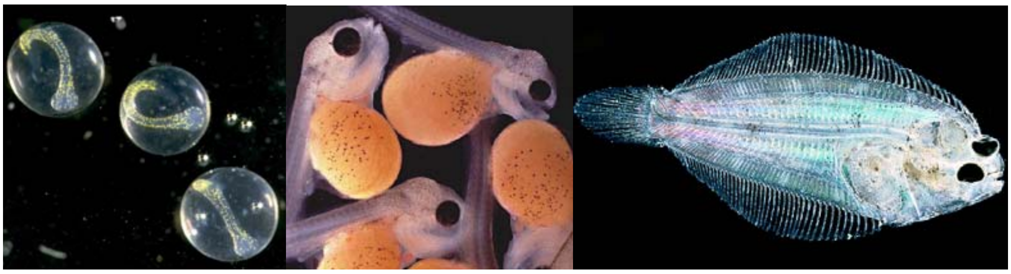
Report number C026/11



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Summary

The initial sampling grid of the year-round ichthyoplankton survey was designed to cover all spawning concentrations which potentially can contribute to the larval population on the Dutch continental shelf (NCP), based on known spawning concentrations and general patterns of residual currents. However, the time required to cover this grid surpassed the shipping time available. A modelling study was carried out to evaluate the initial sampling grid and to examine if the coverage could be reduced without violating the aims of the ichthyoplankton survey. The modelling results showed that the westernmost stations of the initial sampling grid will only contribute substantially to the larval population on the NCP in the case of above average currents. However, the chances of 'above-average-currents' are difficult to quantify because of variability in hydrodynamics on a bi-weekly (spring-neap cycle) to annual scale. An option for a reduced sampling grid, complying with the time restraint and based on the modelling results, is put forward. From a scientific point of view, the initial grid is advised, since it covers the entire southern North Sea. This grid furthermore *ensures* that all spawning concentrations which potentially can contribute to the larval population on the NCP are covered. Although the initial grid is preferred, the reduced grid will probably be sufficient to address the specific focus of the Shortlist Masterplan Wind research, i.e. the spatial and temporal distribution of larvae on the NCP. Major disadvantage of the reduced grid is the loss of coverage of the western spawning populations, but the probability that these spawning populations contribute to the NCP larval population is small.

Contents

1 Introduction

Within the research programme “Shortlist Masterplan Wind” (SMW), a year-round ichthyoplankton survey is being carried out. The sampling area is based on known spawning concentrations and prevailing currents. The English Channel and the south-western North Sea are important spawning areas for many fish species (Teal et al. 2009, 3 examples are presented in Figure 1). The prevailing currents (Figure 2) transport eggs and larvae from these areas towards the Dutch continental shelf (NCP). Therefore it is necessary to extend the sampling area to the south and west of the NCP. The initial sampling grid (Figure 3) covered all known spawning concentrations in the southern North Sea and all areas that may contribute to the larval population on the NCP based on general maps of residual currents. This sampling grid was sampled during the first (April 2010) and second cruise (May 2010) of the year-round ichthyoplankton survey.

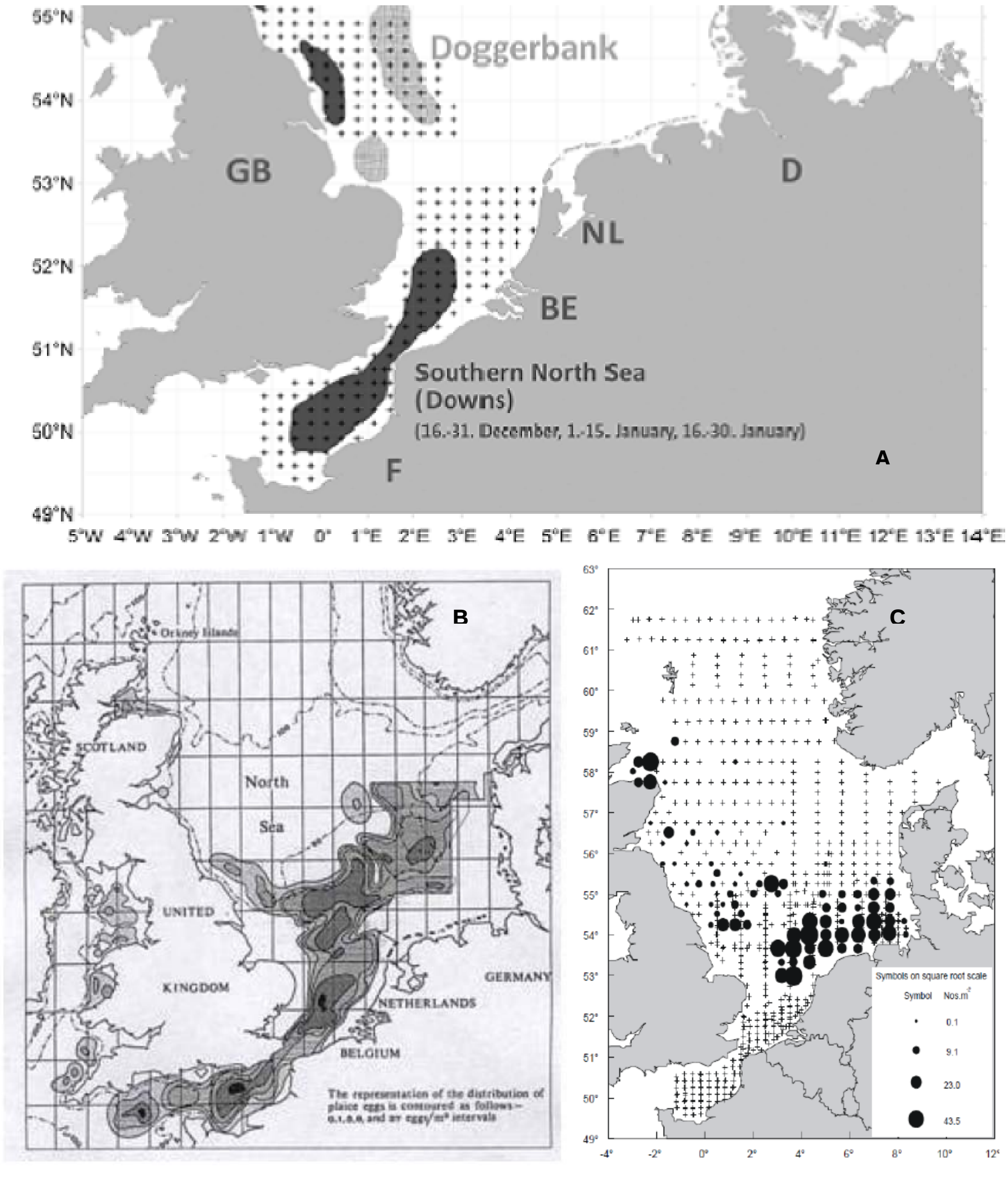

Figure 1. Spawning distributions of herring (A), plaice (B) and sprat (C) taken from the literature (see Teal et al. 2009 for a review of published spawning distributions).

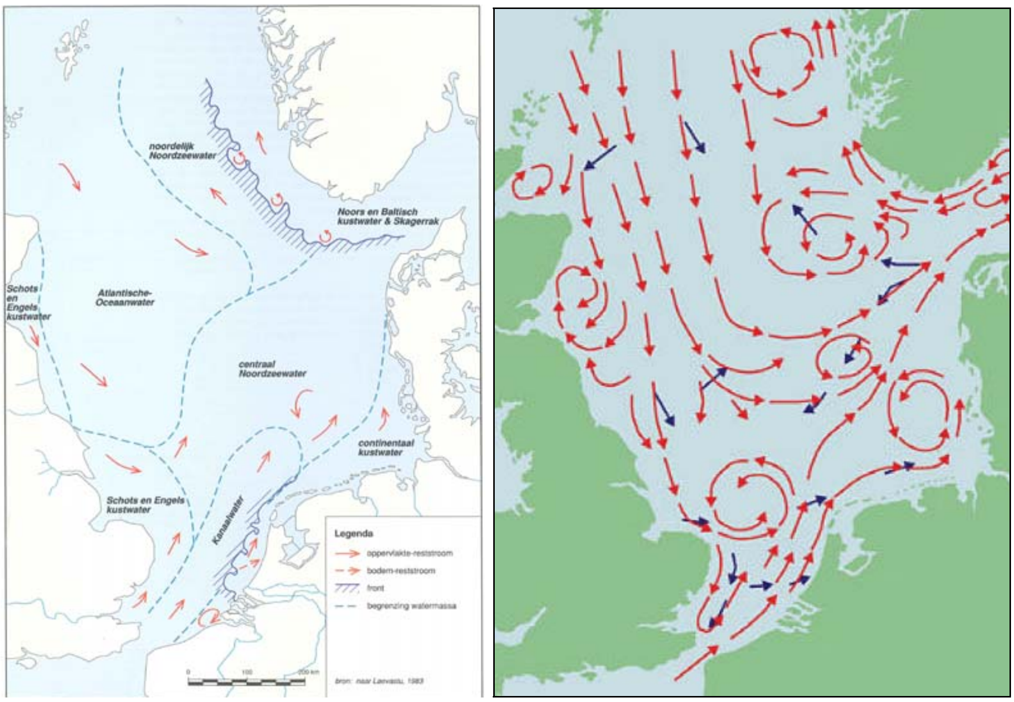

Figure 2. General patterns of residual currents in the North Sea (after Laevastu 1983 in ICONA 1992).

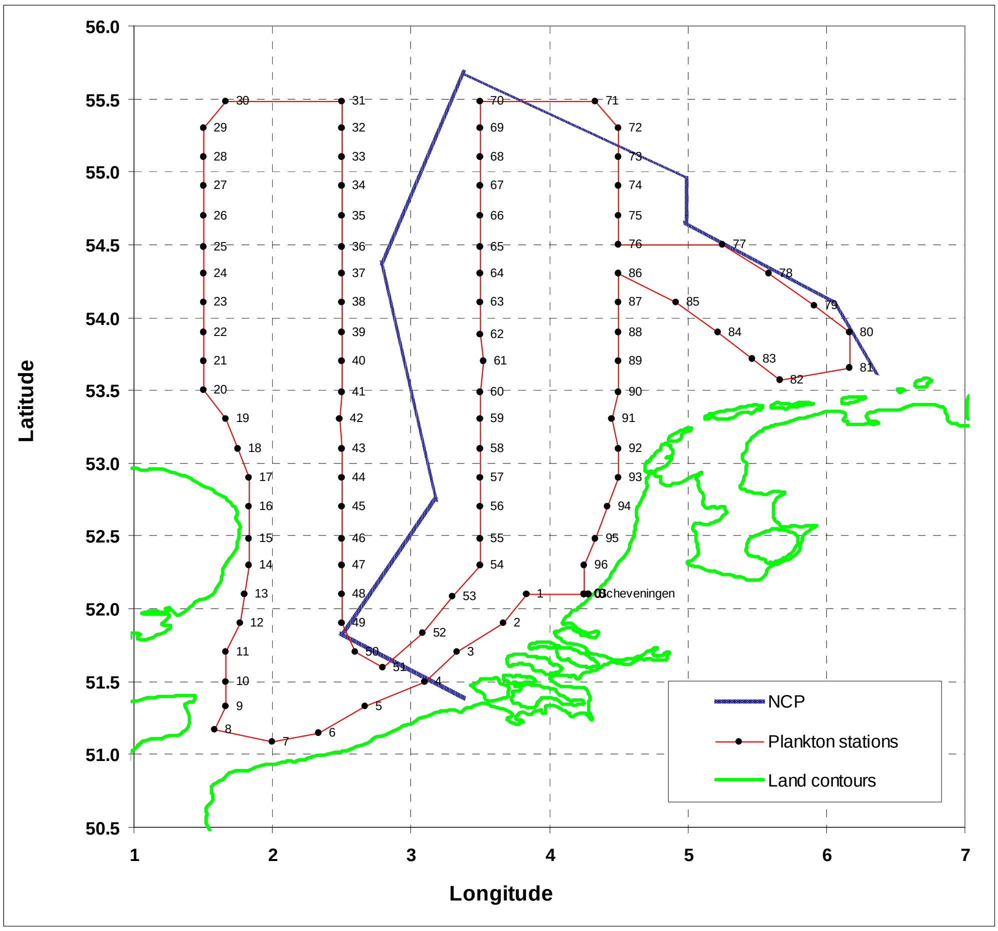

Figure 3. Initial survey grid consisting of 96 stations. This grid can be sampled in 5-6 days (from 8:00am on Monday to 9:00am on Saturday) if an overall speed of 11 knots is achieved.

2 Aim

The aim of this report is to evaluate the initial sampling grid of the SMW ichthyoplankton survey. Coverage of this initial grid posed problems with regard to the shipping time required. Therefore the question was raised if the coverage can be reduced without violating the aims of the ichthyoplankton survey.

3 Modelling study

A brief modelling study was carried out to examine the expected transport patterns of eggs and larvae 'released' at selected stations of the sampling grid. The modelling was done by Deltares, using a previously developed larval transport model (Bolle et al. 2005).

3.1 Methods

The approach taken for this modelling exercise had to be largely simplified compared to previous modelling studies (Bolle et al. 2005, Bolle et al. 2009, Dickey-Collas et al. 2009, Erftemeijer et al. 2009). Hydrodynamic forcing was primarily based on an average spring-neap cycle, as actual hydrodynamics for 2010 are not available and the choice of any other period or year would be arbitrary. However, to illustrate the degree of variability in transport patterns caused by hydrodynamic variability, alternative periods of hydrodynamic forcing were also used. No species-specific characteristics or behaviour were assigned to the fish eggs and larvae. It is important to bear in mind that this is a simplification of reality. Previous studies have shown that larval behaviour and seasonal or annual variations in hydrodynamics can greatly affect transport patterns (Bolle et al. 2009).

Transport was modelled for 'substances' (representing fish eggs and larvae) discharged at selected stations of the sampling grid. The duration of a discharge was 24 hours and the distribution after 7, 14, 21 and 28 days was calculated. Seven days represents a short egg incubation period (for species spawning in spring or summer, e.g. sole) and 21 days represents a long egg incubation period (for species spawning in winter, e.g. plaice). The distribution after 28 days is an estimation of the distribution at the time of the next survey. The results reflect the relative distributions of eggs and larvae (on a logarithmic scale). The absolute numbers are fictitious as no mortality is included in the model simulations.

3.2 Transport from current stations based on average hydrodynamics

Transport was modelled, based on average hydrodynamics, for 6 stations on the westernmost transect: stations 8, 11, 15, 20, 25 and 30 (Figure 3). The distribution after 7, 14, 21 and 28 days is presented in Figures 4a – 4f.

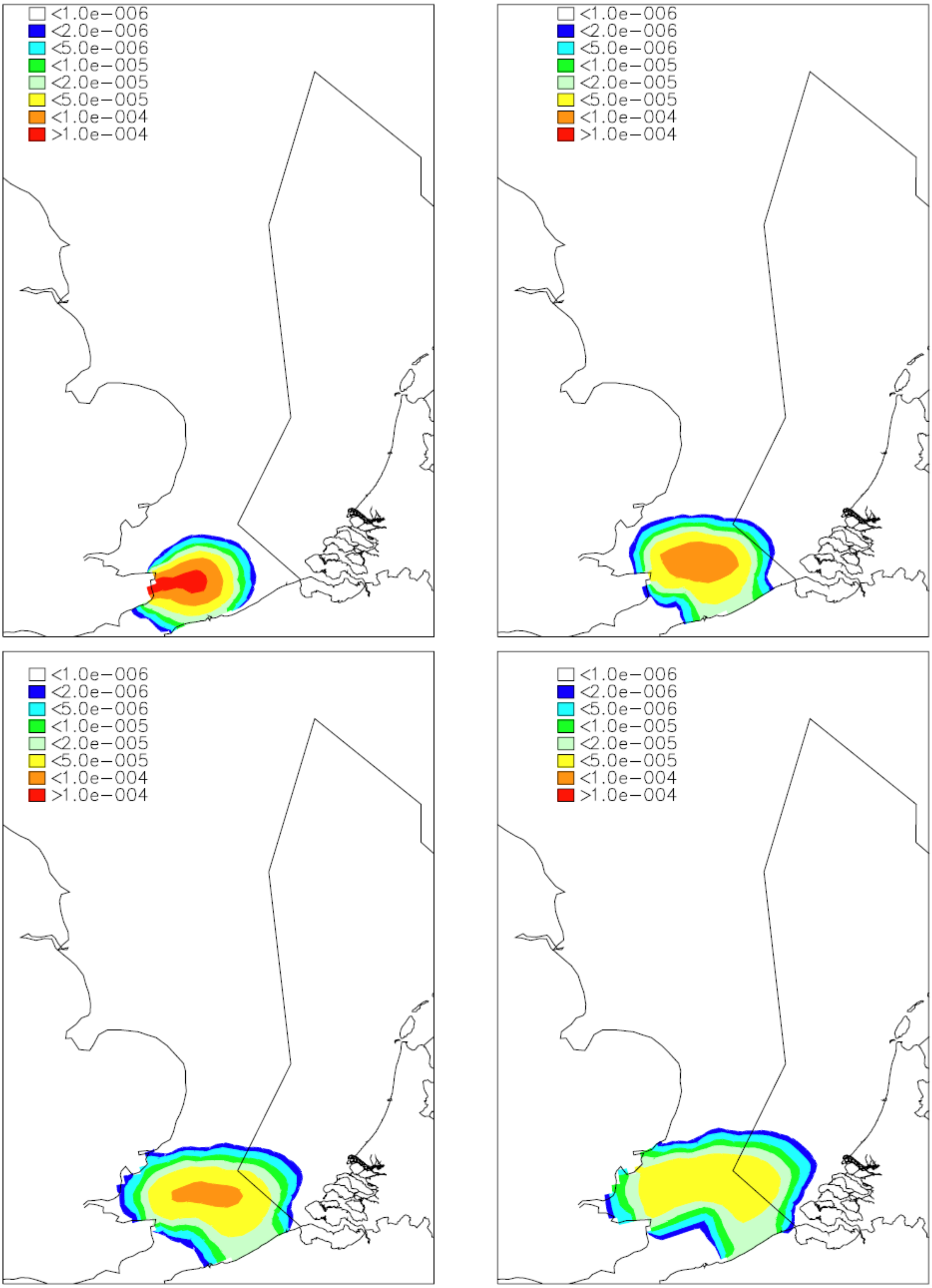

Figure 4a. Station 8. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

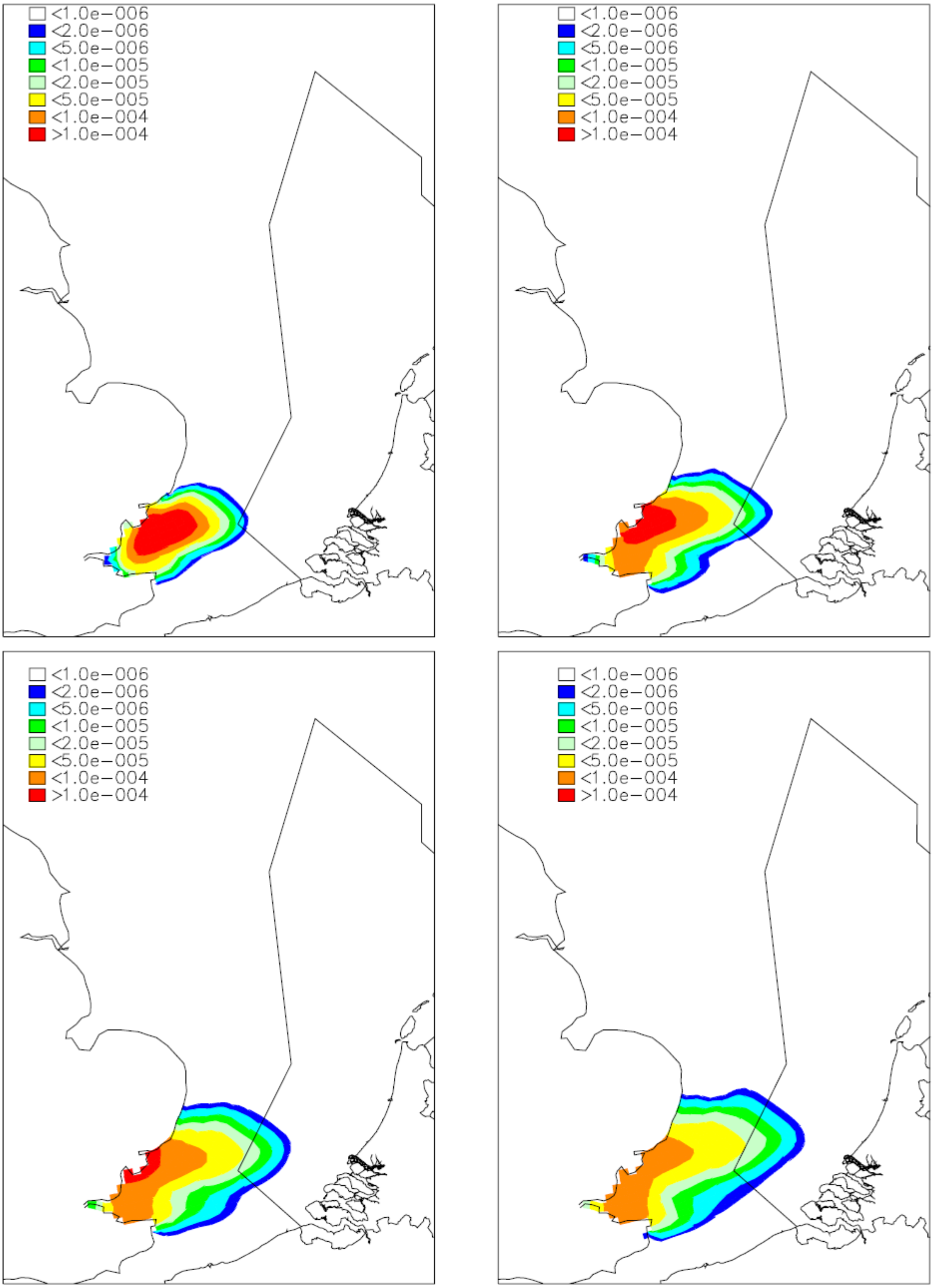

Figure 4b. Station 11. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

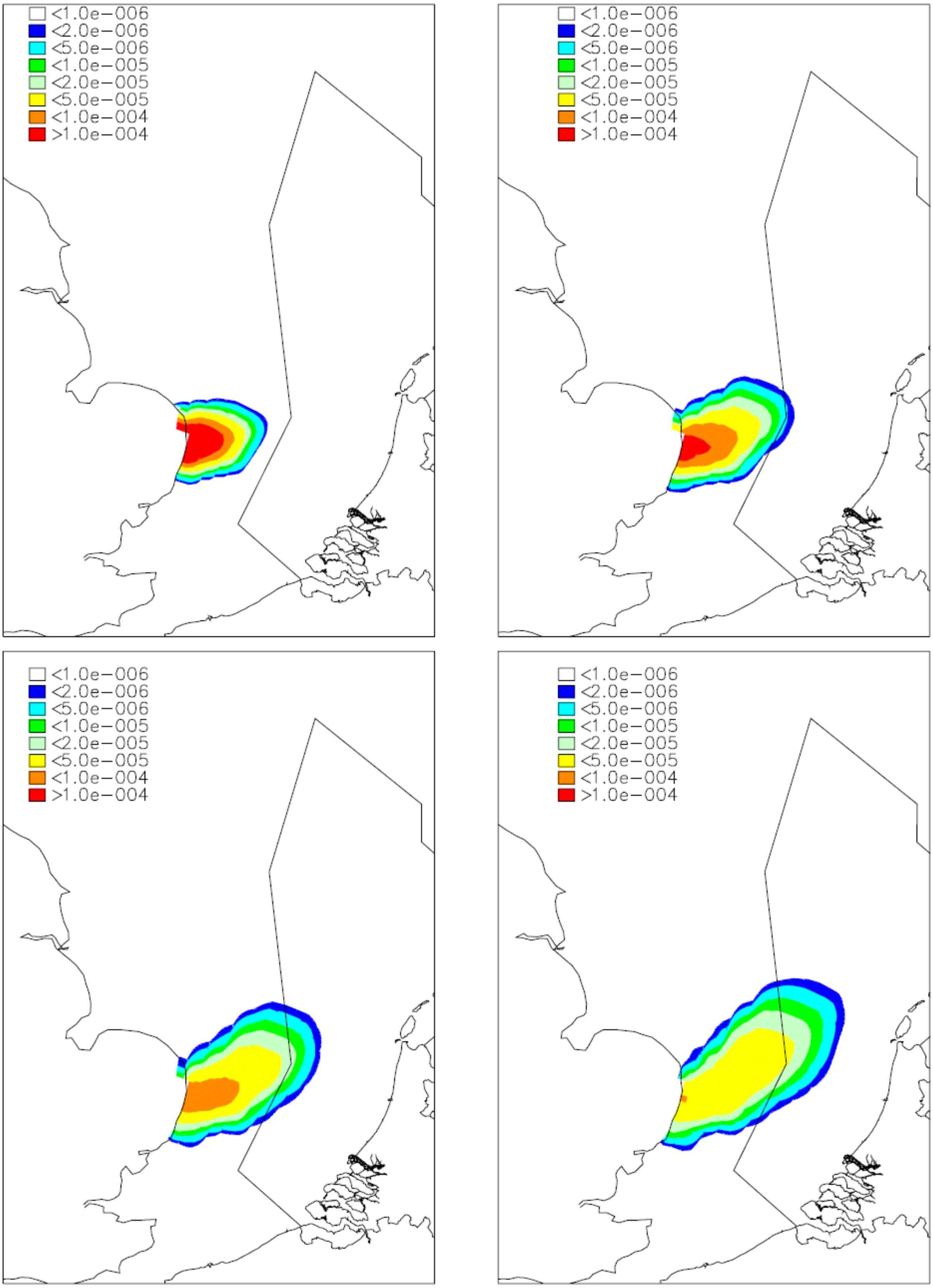

Figure 4c. *Station 15. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.*

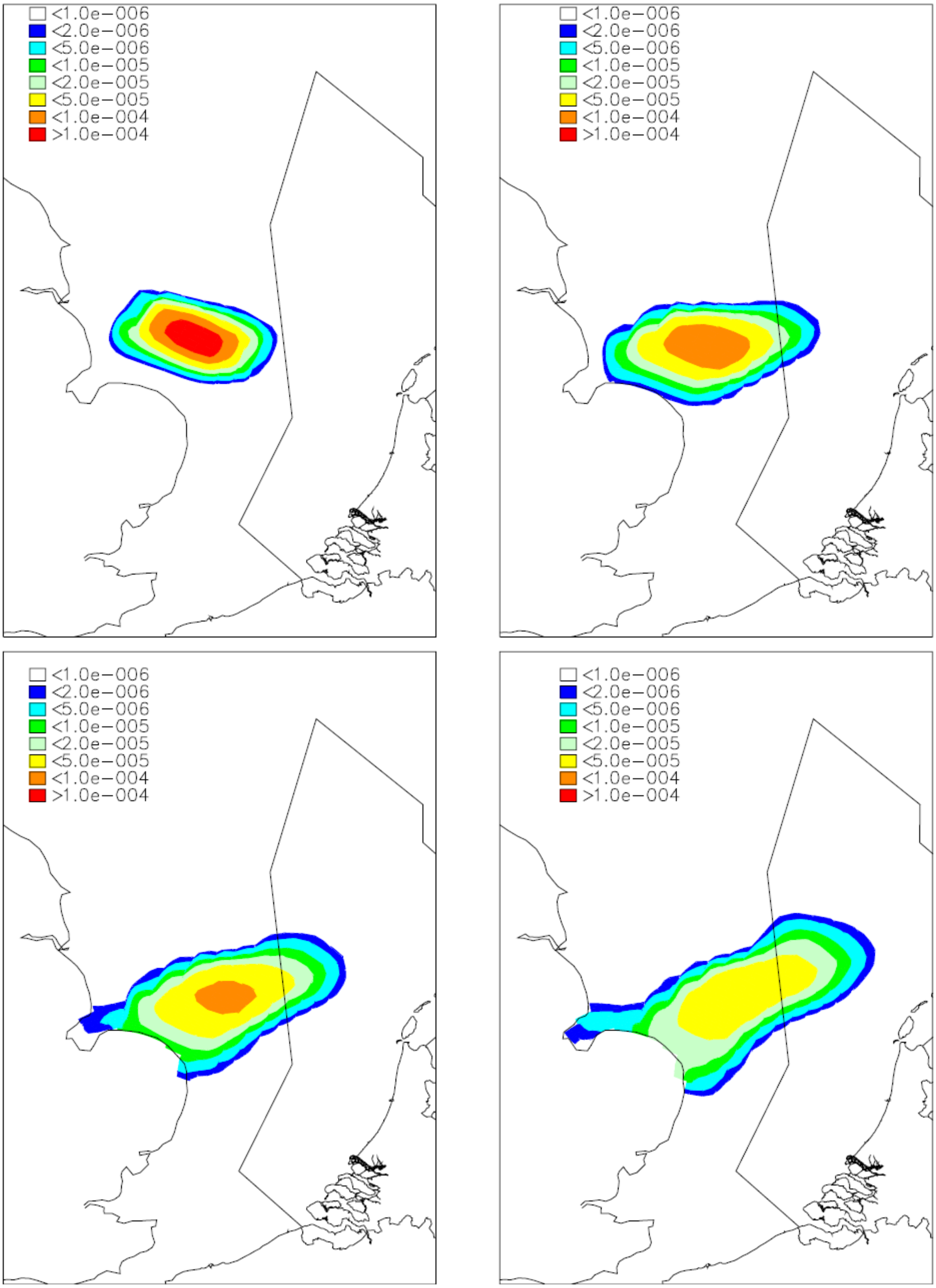

Figure 4d. Station 20. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

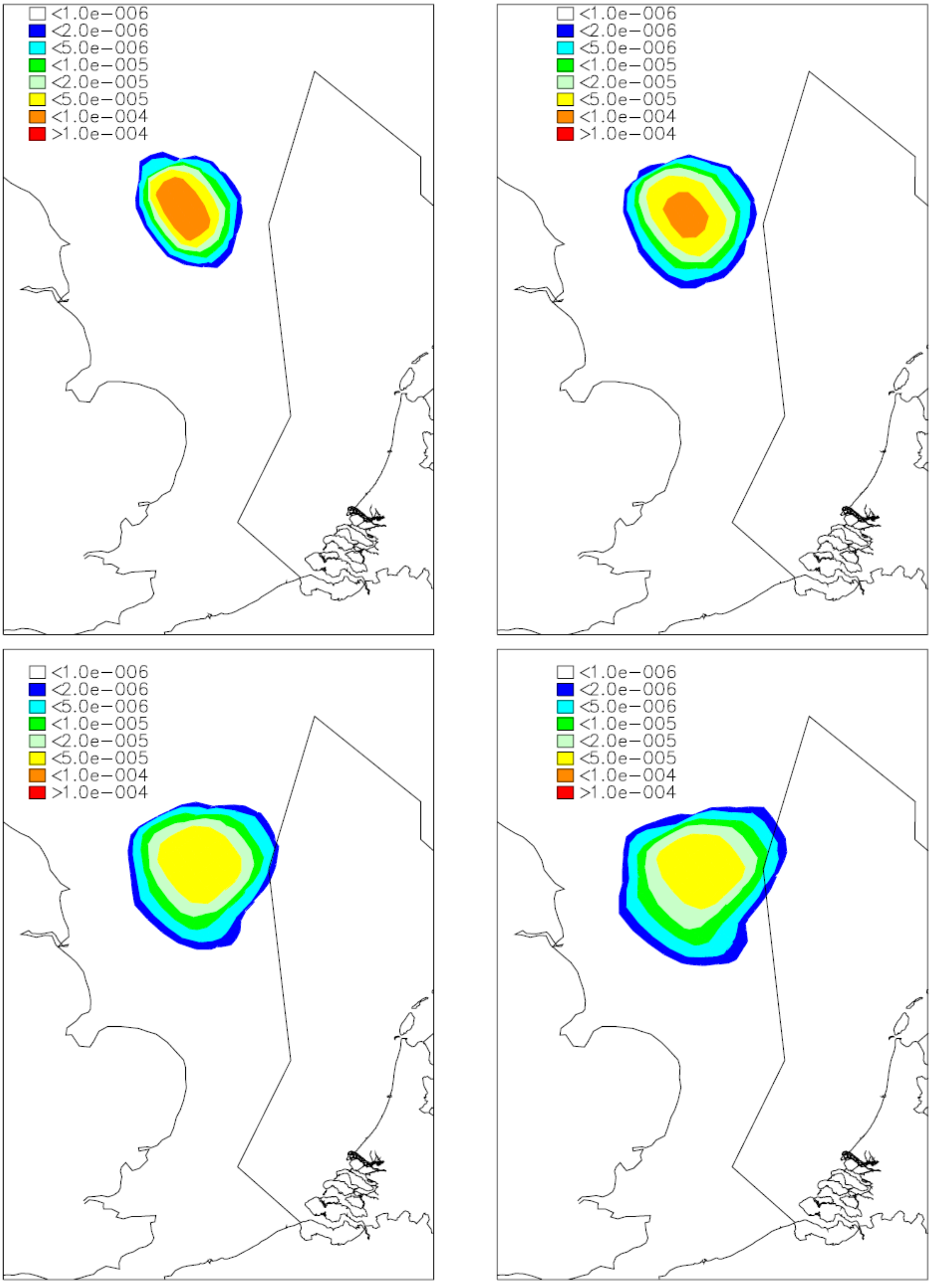

Figure 4e. Station 25. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

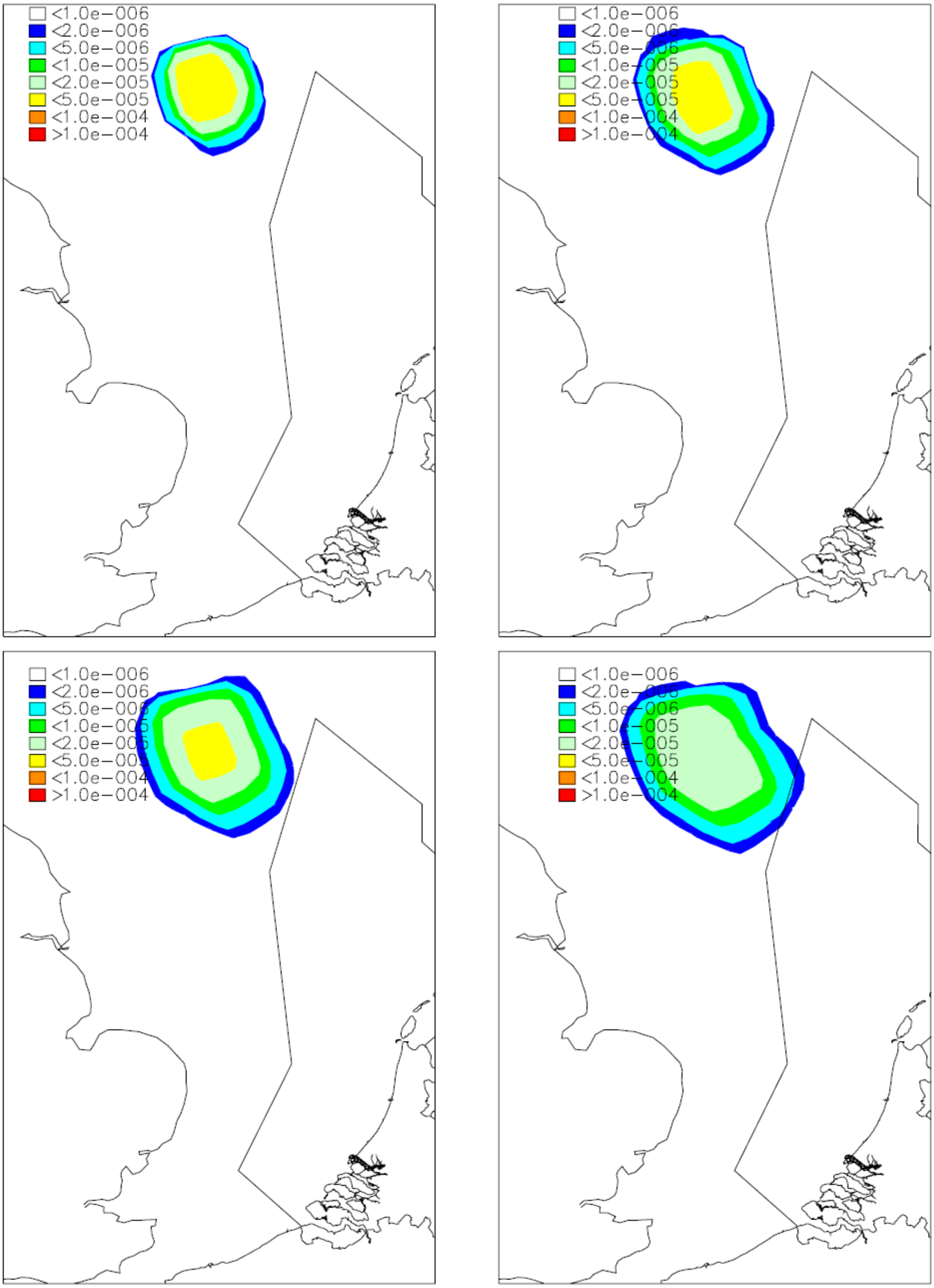

Figure 4f. Station 30. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

3.3 Variability in transport related to hydrodynamic variability

To illustrate the effect of variability in hydrodynamics, transport from stations 20 and 25 was compared using different hydrodynamic forcing: an average spring-neap cycle (Figure 4d and 4e), a 4 week period in 2002 (Figure 5), and a 4 week period in 1996 (Figure 6). These hydrodynamic periods were roughly selected from the previous modelling studies because they more or less showed the range of differences in transport patterns (within a limited number of years and seasons). In the previous studies we focussed on transport patterns in the south-eastern North Sea and the extremes in south-western North Sea may fall in other periods. Nevertheless, this comparison does illustrate that the evaluation of the stations may differ depending on which hydrodynamic forcing is used. For stations 20 and 25, none of the eggs/larvae (Figure 6), a small proportion (Figure 4), or 40-60% (Figure 5) reach the NCP within 3 weeks, depending on which hydrodynamic forcing is used.

Residual currents and hence transport patterns not only vary between years and seasons, but may also vary at a smaller temporal scale (i.e. spring-neap cycle). This is illustrated in Figure 7: transport patterns clearly differed if the hydrodynamic forcing was shifted by only 2 weeks.

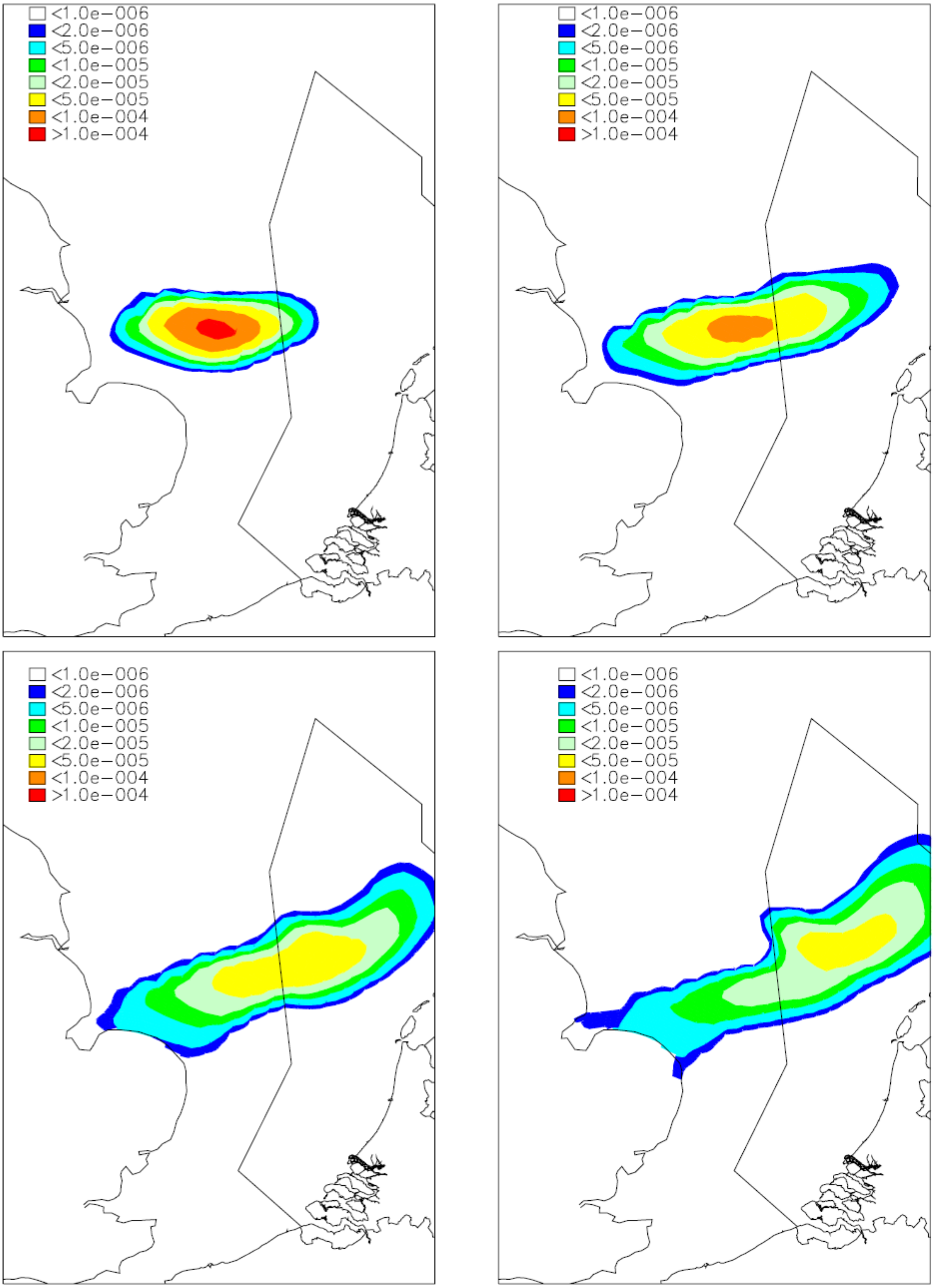

Figure 5a. Station 20. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on hydrodynamics in the period 27 January – 24 February 2002.

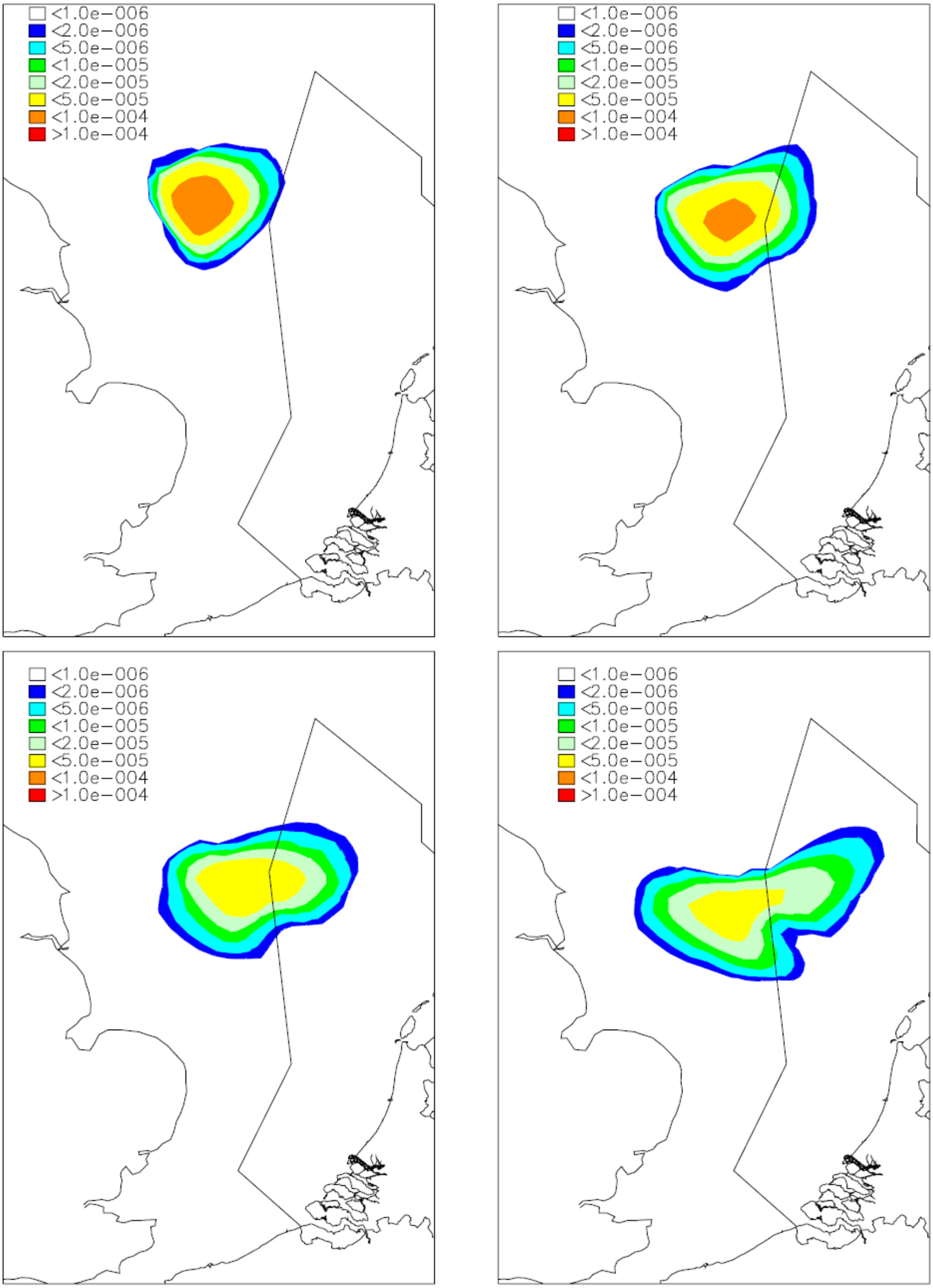

Figure 5b. Station 25. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on hydrodynamics in the period 27 January – 24 February 2002.

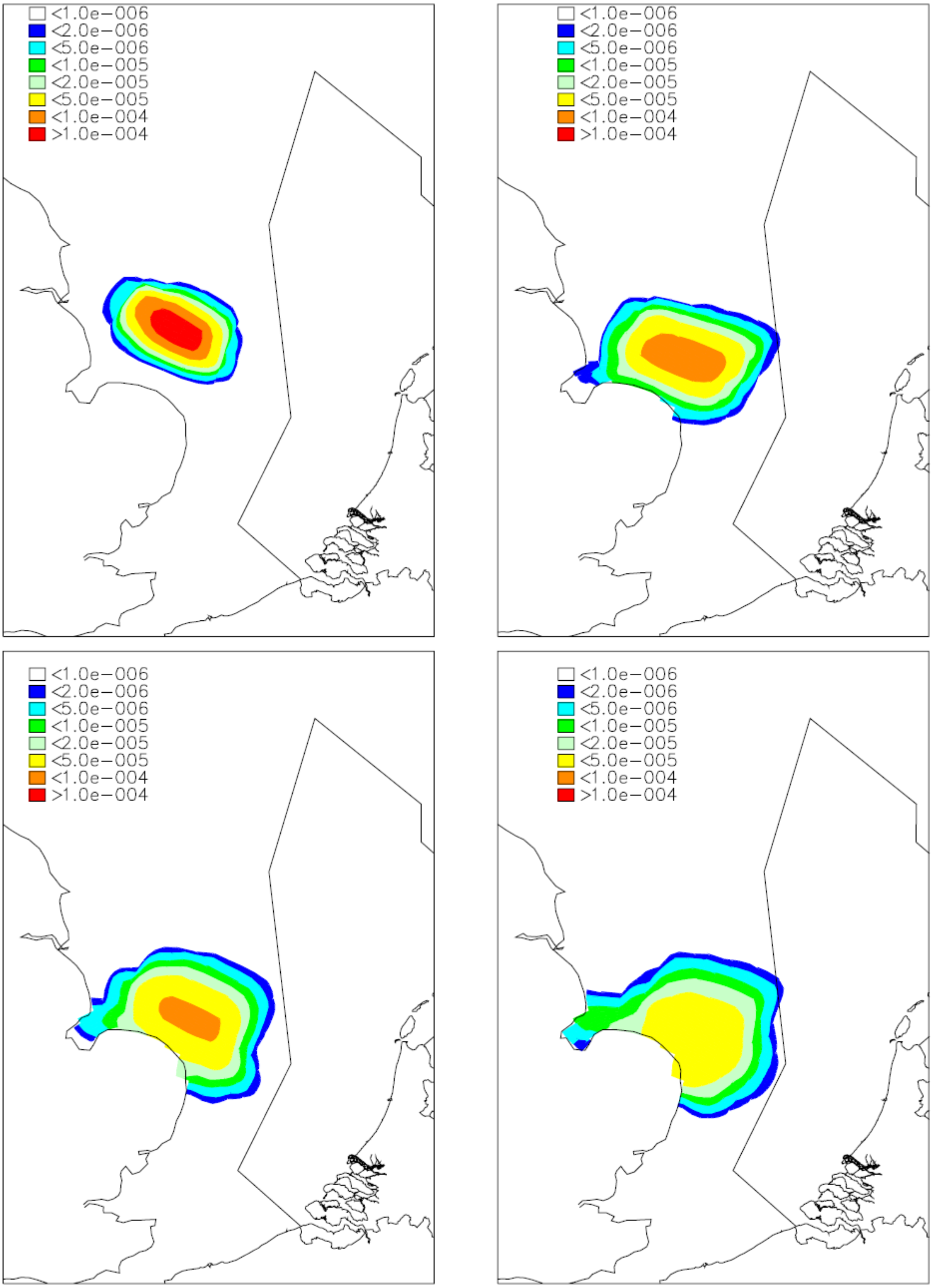

Figure 6a. Station 20. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on hydrodynamics in the period 10 March – 7 April 1996.

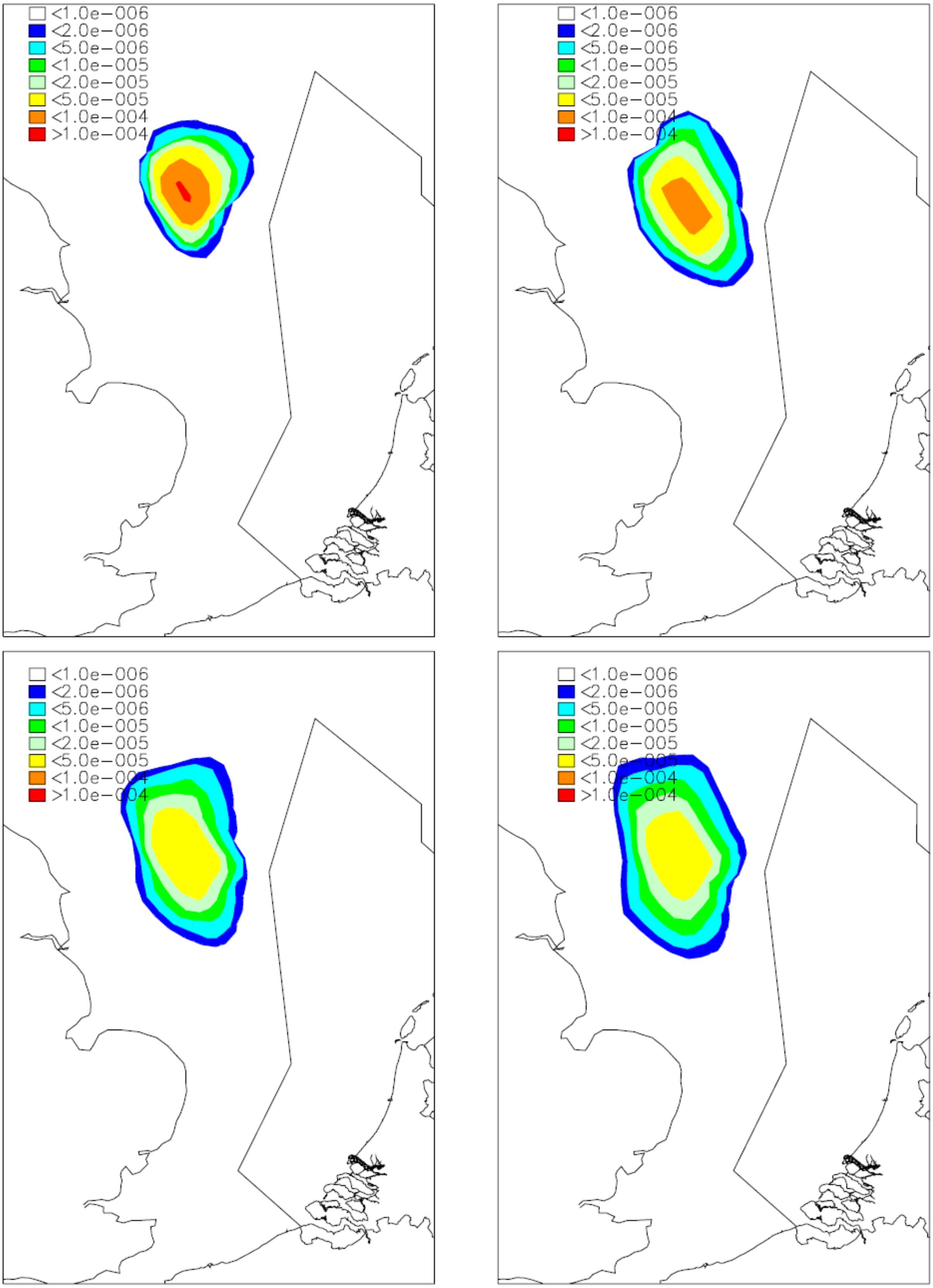

Figure 6b. Station 25. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on hydrodynamics in the period 10 March – 7 April 1996.

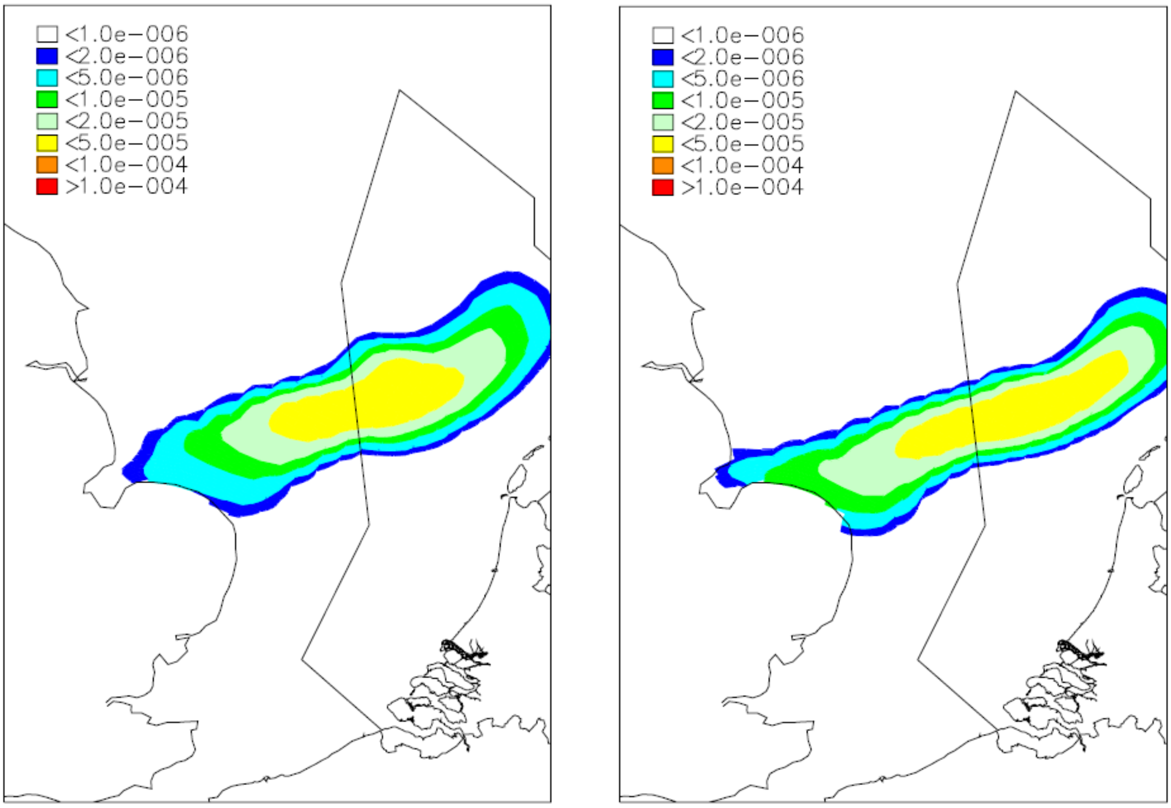

Figure 7a. Station 20. Modelled distribution of eggs and larvae after 21 days based on 2 hydrodynamic periods in 2002 (left: 27 January – 17 February, right: 10 February – 3 March).

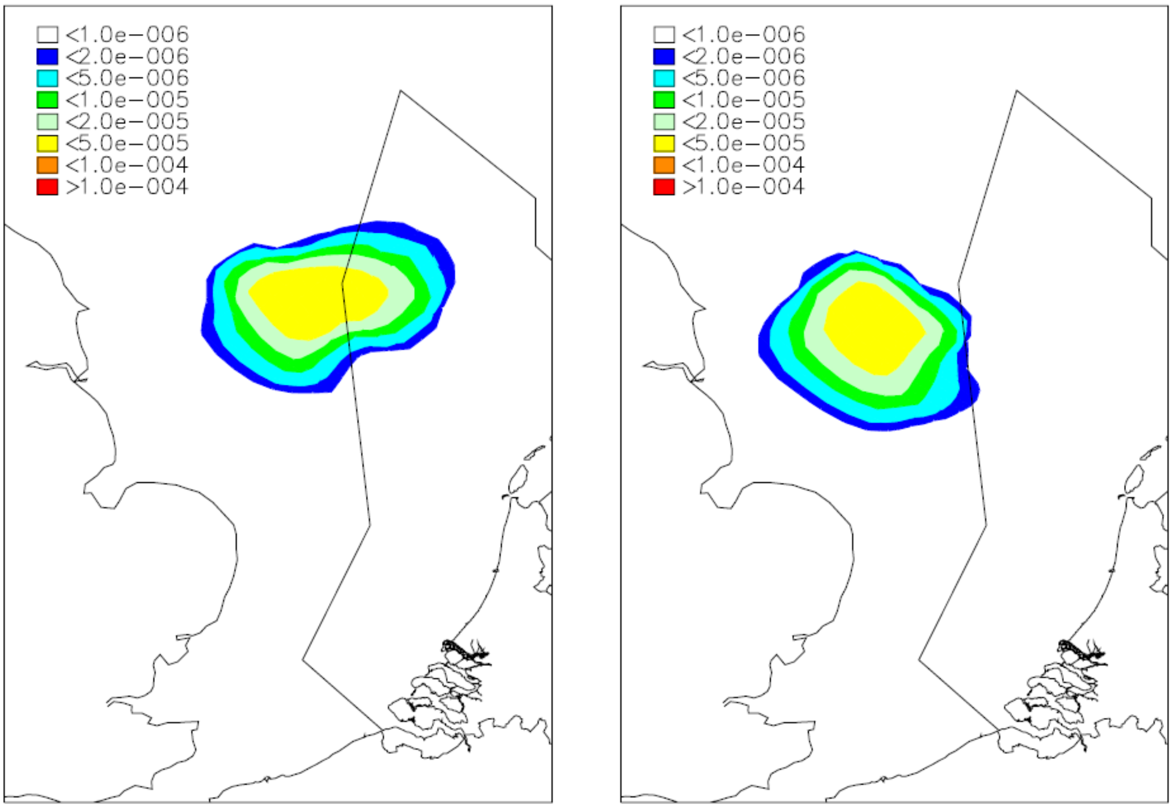

Figure 7b. Station 25. Modelled distribution of eggs and larvae after 21 days based on 2 hydrodynamic periods in 2002 (left: 27 January – 17 February, right: 10 February – 3 March).

3.4 Transport from adjusted stations based on average hydrodynamics

Transport was also modelled for 6 adjusted stations: the 6 stations examined previously (section 3.2) were moved east to 2^{o}15' E at the same latitude. Hydrodynamic forcing was based on an average spring-neap cycle.

An eastward adjustment of the westernmost transect will result in an increase of the proportion of eggs/larvae that reach the NCP within 1-3 weeks. Exact proportions have not been calculated, but visual inspection of Figure 8 indicates that, under average hydrodynamic conditions, ±25-50% of the eggs spawned on the 6 adjusted stations will reach the NCP within 3 weeks. These proportions are higher than for the original positions of the stations (Figure 4).

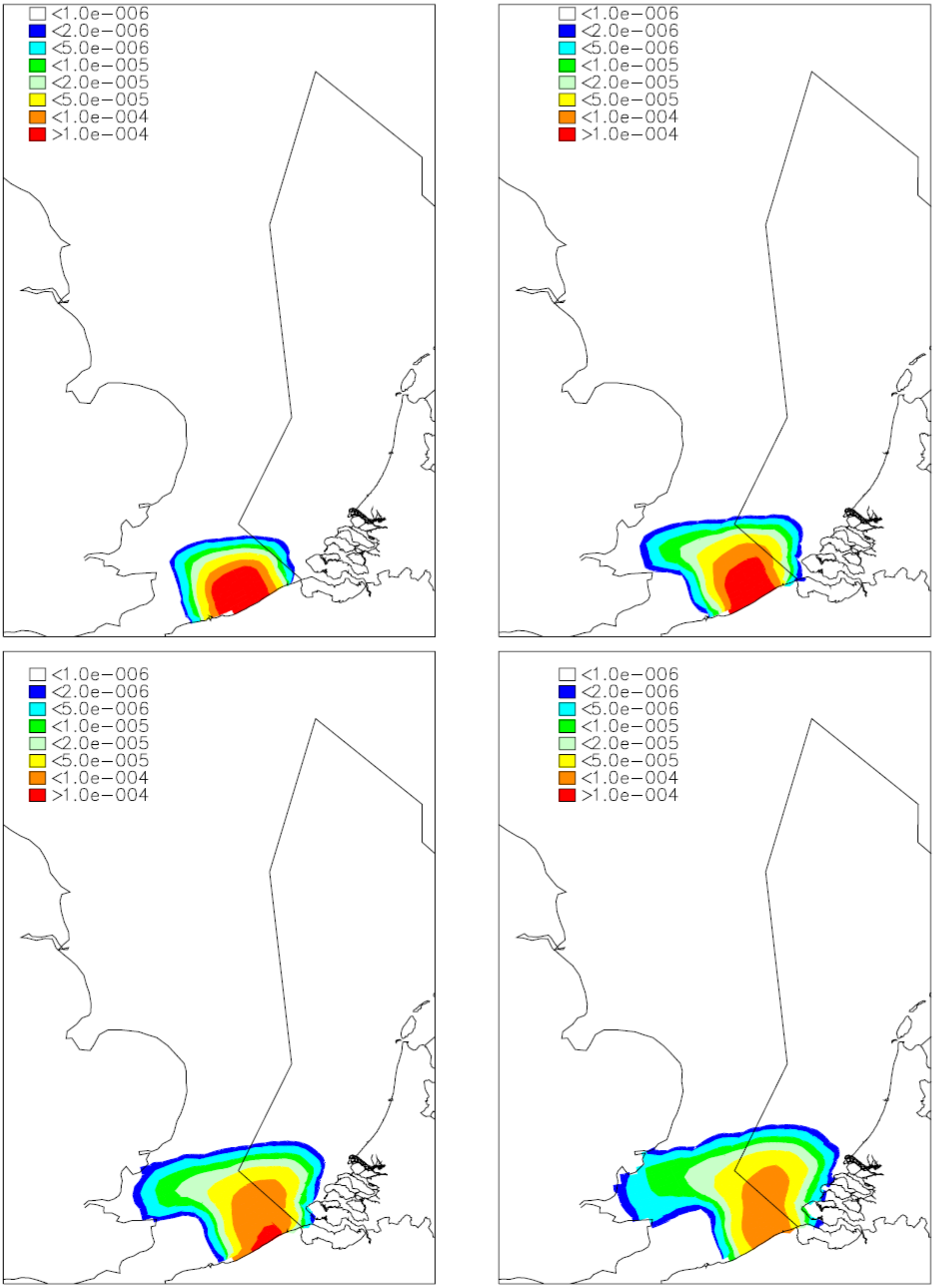

Figure 8a. Station 8 adjusted. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

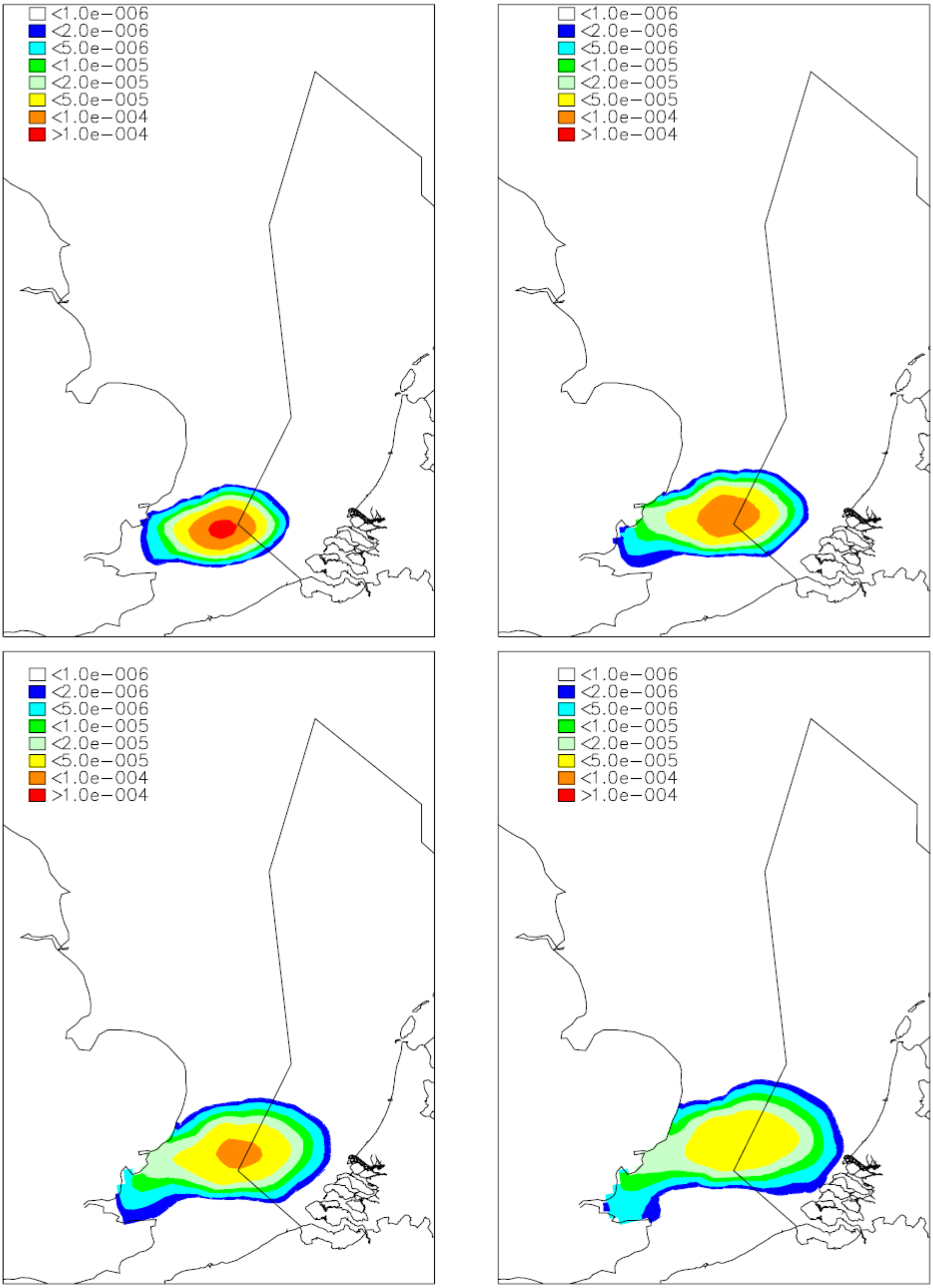

Figure 8b. Station 11 adjusted. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

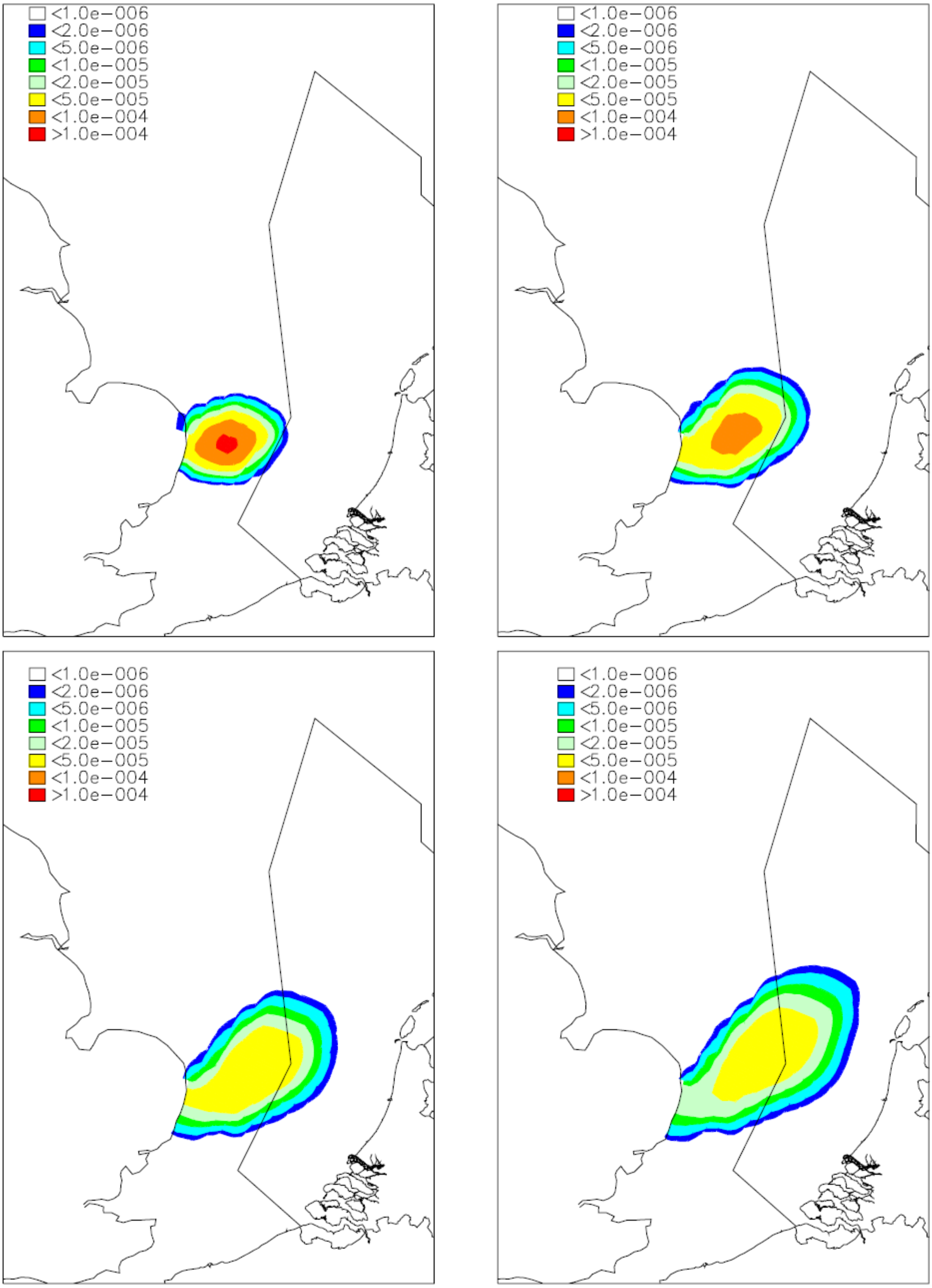

Figure 8c. Station 15 adjusted. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

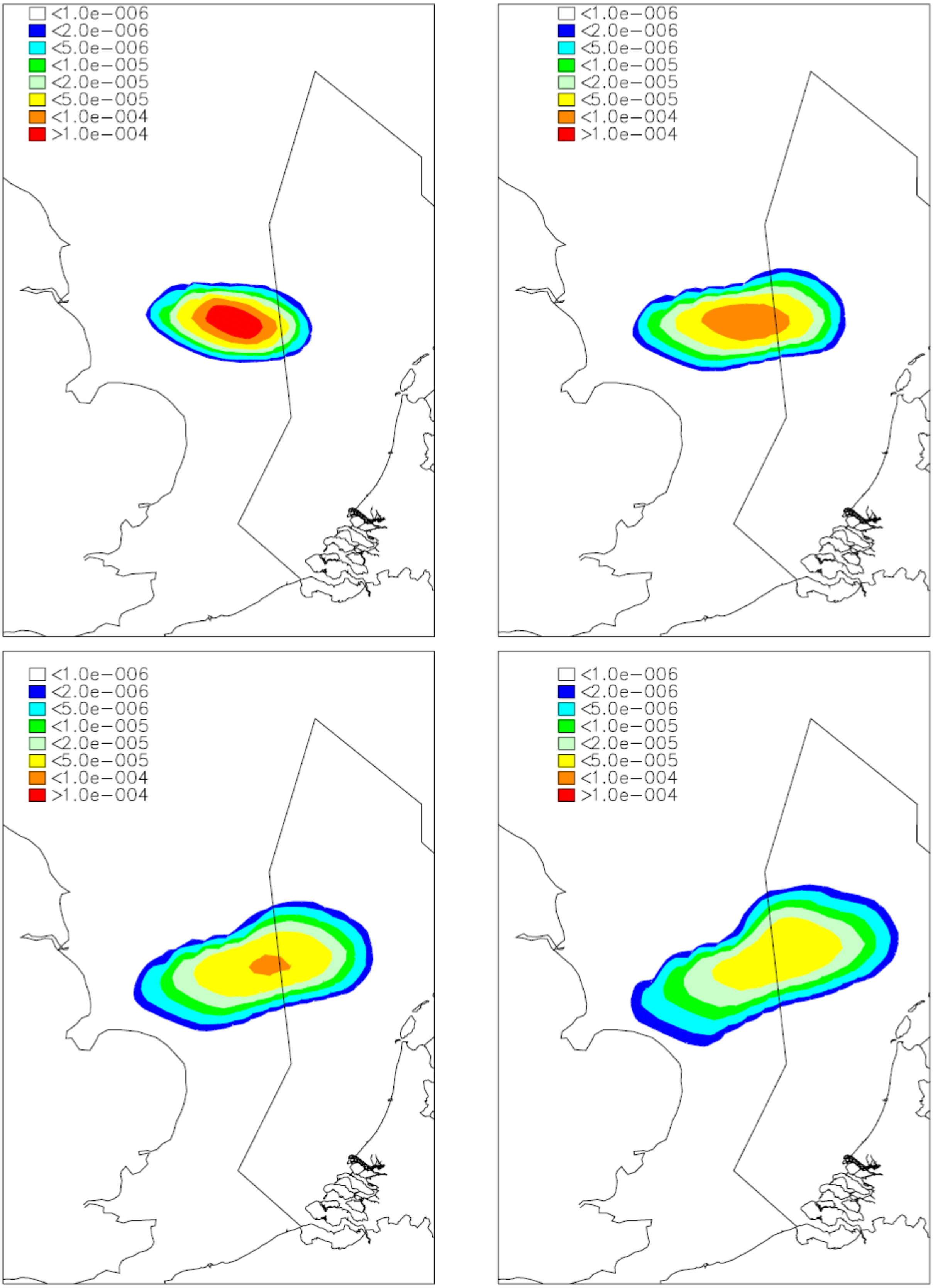

Figure 8d. *Station 20 adjusted. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.*

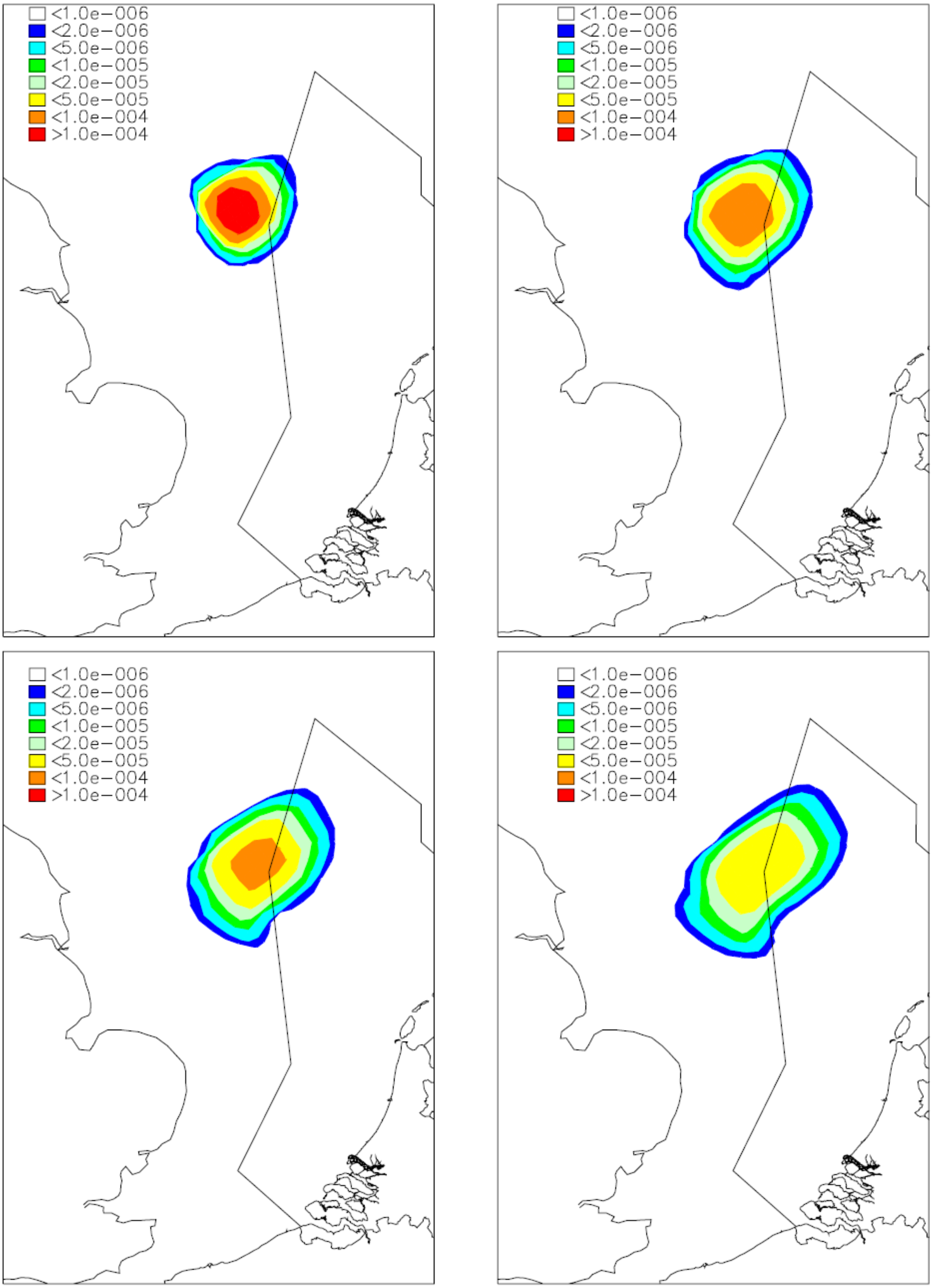

Figure 8e. Station 25 adjusted. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.

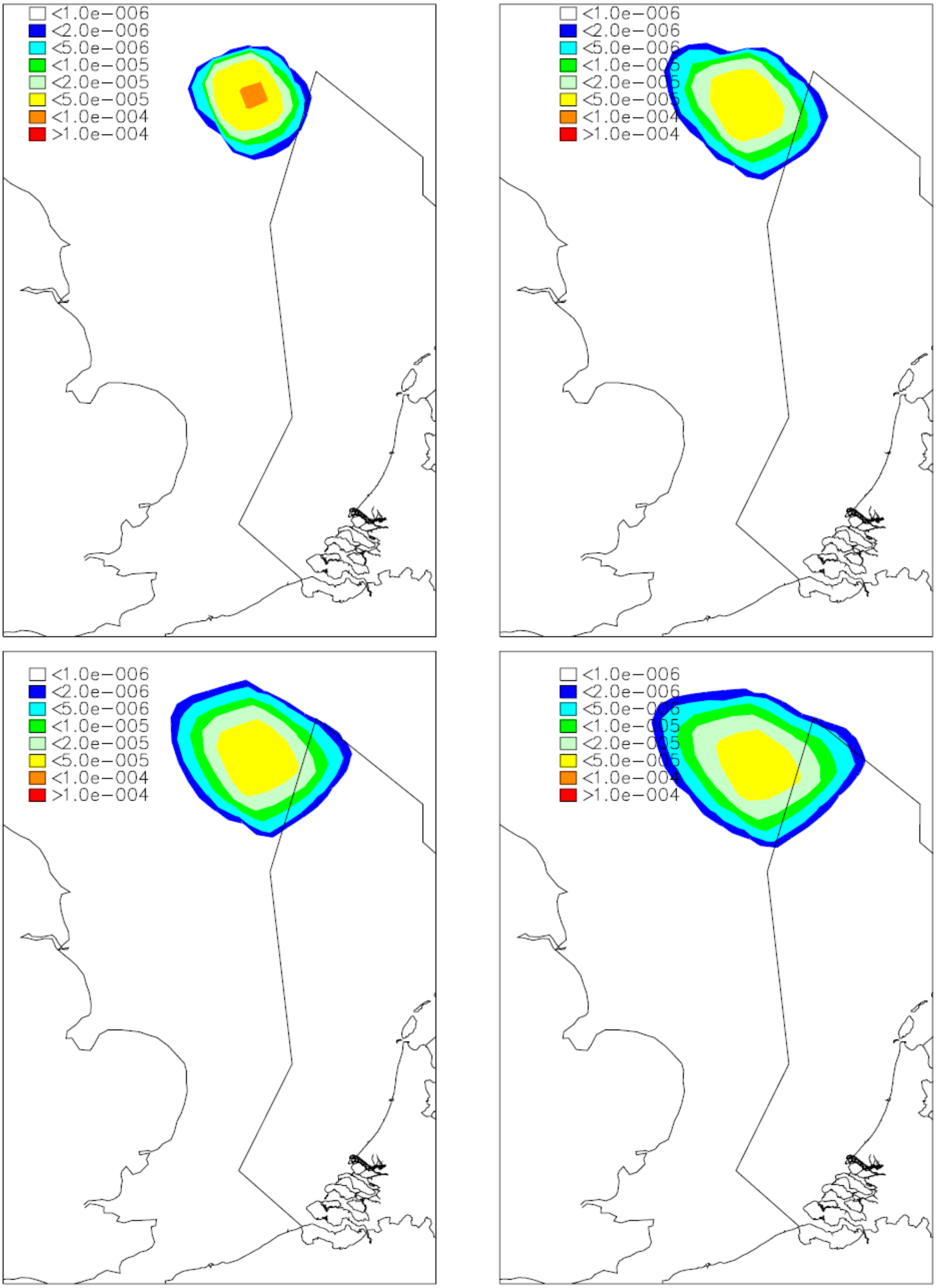

Figure 8f. *Station 30 adjusted. Modelled distribution of eggs and larvae after 7, 14, 21 and 28 days based on average hydrodynamics.*

4 Evaluation of the sampling grid

The modelling results show that the westernmost stations of the initial sampling grid (Figure 3) will only contribute substantially to the larval population on the NCP in the case of above average currents. However, the chances of 'above-average-currents' are difficult to quantify because of variability in hydrodynamics on a bi-weekly (spring-neap cycle) to annual scale. A very tentative guestimate of the probability that eggs from the westernmost stations reach the NCP is 1-10%. The specific aim of the ichthyoplankton survey, within the Shortlist Masterplan Wind context, is to estimate the spatial and temporal distribution of fish larvae on the NCP. Focussing on this specific aim and taking into account the modelling results, would lead to the conclusion that the sampling grid can be compressed in easterly direction.

An option for compressing the sampling grid in easterly direction is presented in Figure 9. The westernmost transect is shifted to $2^{o}15'$E, corresponding to the model runs presented in section 3.4. Advantage of this sampling grid compared to the initial sampling grid is a higher resolution, especially in the eastern part of the NCP. Major disadvantage of moving the sampling grid to the east is that spawning concentrations in the western part of the southern North Sea may be missed. Examination of published spawning distributions (collated in Teal et al. 2009) shows that by shifting the station grid as proposed in Figure 9, spawning concentrations off Flamborough Head (± 54^{o}N and 1.5^{o}E) will be missed. Spawning concentrations in this area have been observed in several species (e.g. sprat, cod, whiting, plaice) during several years.

The pivotal question within the context of the Shortlist Masterplan Wind research is: do these spawning concentrations off Flamborough Head contribute to the larval populations on the NCP? Based on the modelling studies it appears that they will only contribute substantially to the NCP in the case of above average currents. It should however be noted that a small proportion of high egg densities may contribute more larvae to the NCP than a large proportion of low egg densities. Therefore coverage of the western spawning concentrations (i.e. Figure 3) is preferred.

A logistic aspect, which has to be taken into account, is a time restraint on the shipping time due to labour conditions. The request was put forward to change the sampling grid so it can be completed within 5 days (i.e. estimated arrival time Friday evening). It is impossible to maintain the spatial coverage of the initial sampling grid (Figure 3) given the imposed time restraint. The spatial coverage is reduced in the second grid based on the modelling results (Figure 9), but this grid cannot be sampled within 5 days either. Therefore a third option is put forward (Figure 10). This option is based on the second option, with a small reduction of both spatial coverage as well as resolution. The loss of coverage and resolution in the 3rd option compared to the 2nd option is considered to be marginal.

From a scientific point of view, the initial grid (Figure 3) is advised, since it covers the entire southern North Sea. This option furthermore *ensures* that all spawning concentrations which potentially can contribute to the larval population on the NCP are covered. Although the initial grid is preferred, the third grid (Figure 10) will probably be sufficient to address the specific focus of the Shortlist Masterplan Wind research, i.e. the spatial and temporal distribution of larvae on the NCP. Major disadvantage is the loss of coverage of the western spawning populations, but the probability that these populations contribute to the NCP larval population is small.

The gap in the sampling grid above the islands of Texel and Vlieland (which occurs in all 3 options for the sampling grid) is regretted, because some species mainly spawn in coastal waters (e.g. sole, Bolle et al. in prep). There is, however, no possibility of increasing the number of stations in this area without reducing the efficiency of sailing between the stations.

During the first survey, the stations were sampled from west to east. This sequence was questioned with regard to the priority of the stations (i.e. the risk of losing the last stations if bad weather occurs). We propose to maintain the current sequence for 2 reasons. Firstly, important spawning concentrations are located in the western part of the (adjusted) survey area. Secondly, sampling takes place in the same direction as the residual currents. This introduces the risk of double counting a patch of eggs/larvae, but this is preferred to the risk of missing a patch of eggs/larvae, which would arise if we would sample the other way around.

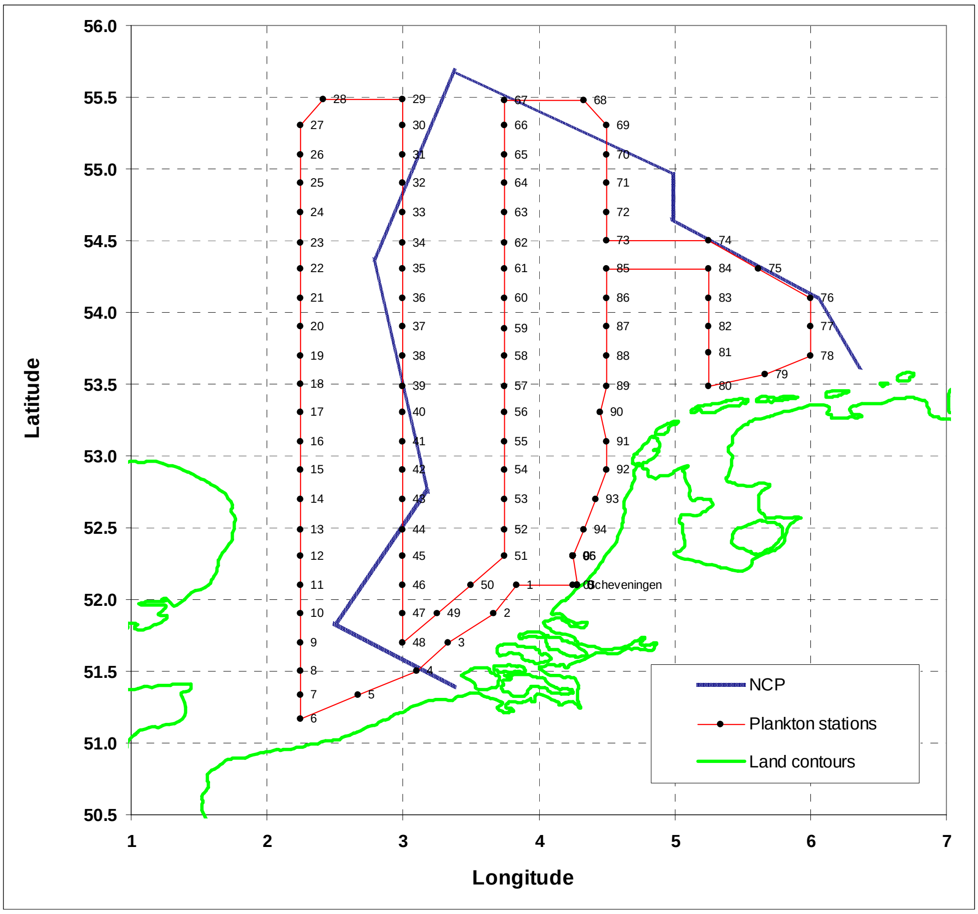

Figure 9. *Survey grid consisting of 95 stations in which the spatial coverage is reduced and the spatial resolution is increased compared to the original survey grid (Figure 3). This grid can be sampled in 5-6 days (from 8:00am on Monday to 3:00am on Saturday) if an overall speed of 11 knots is achieved.*

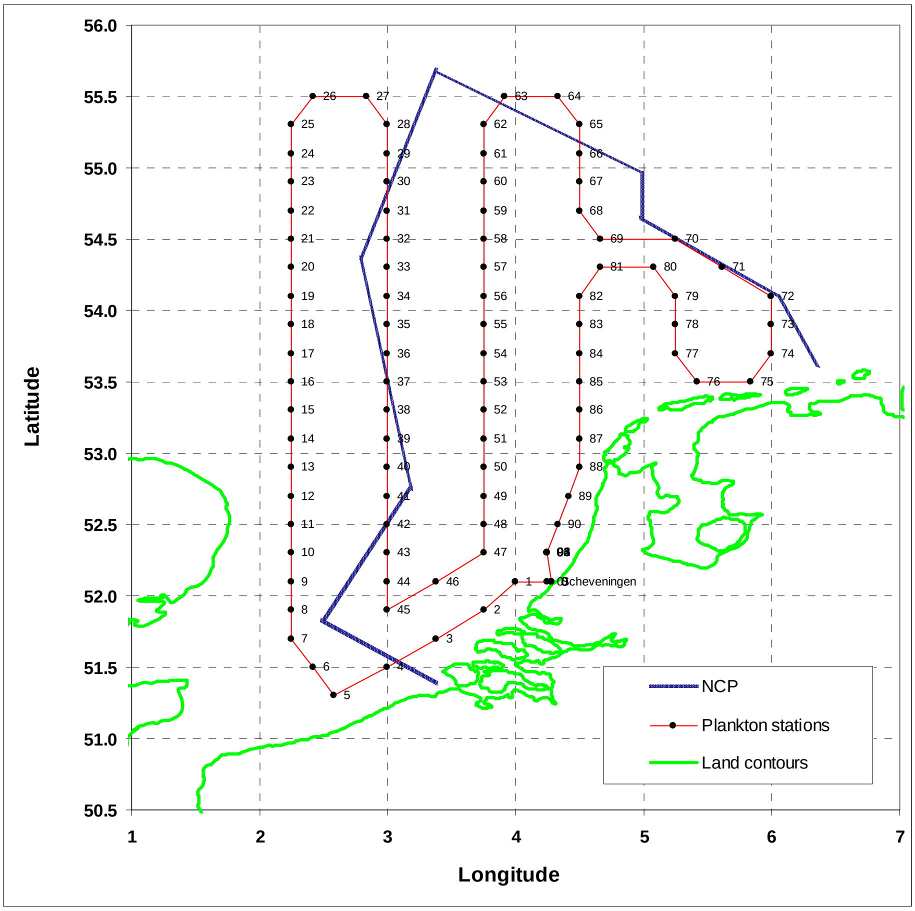

Figure 10. Survey grid consisting of 91 stations in which the spatial coverage and resolution are decreased compared to the previous survey grid (Figure 9). This grid can be sampled in 5 days (from 8:00am on Monday to 9:00pm on Friday) if an overall speed of 11 knots is achieved.

5 Future research

After completion of the year-round ichthyoplankton survey, further transport modelling is recommended to enable extrapolation of the spatial distribution of fish larvae to periods between the cruises. Hydrodynamic transport modelling, other than the limited study reported here, is not included in the current assignment. Future modelling studies will require an update of the existing larval transport model, which includes the following improvements and elaborations:

- Resolution:
  Since the development of the larval transport model, vertical and horizontal resolution of the underlying hydrodynamic model has been improved (by domain decomposition and an increase of the number of water layers). The resolution and functions of the larval transport model need to be adapted accordingly.

- Actual forcing of hydrodynamic model:
  The hydrodynamic model needs to be forced with actual meteorological and river discharge data corresponding to the period of the ichthyoplankton survey (April 2010 – April 2011).

- Parameterisation of model:
  The larval transport model has been parameterised for plaice, sole and herring. These parameterisations need to be updated (due to the increase of vertical resolution) and to be elaborated for other species or groups of species.

- Spawning distributions:
  In the previous studies, spawning distributions were used as starting point for transport modelling (Bolle et al 2005, Bolle et al 2009, Dickey-Collas et al 2009, Erftemeijer et al. 2009). In the present study, single discharges (at selected stations) were used. For future studies, spawning distributions are recommended. Data on spawning distributions (i.e. the distribution of stage 1 eggs by species or group of species) are collected during the year-round ichthyoplankton survey.

- Langrangian transport model
  The current larval transport model is based on a Eularian approach (finite volume model). For future modelling a Langrangian approach (particle tracking) is considered to be necessary, primarily because it enables backtracking, but also because it expands the possibilities of modelling temporal distributions in spawning. Combining a Langrangian transport model with the above mentioned resolution is, however, a challenge.

- Mortality:
  Mortality is not included in the present larval transport model and hence the modelled distributions only represent the relative distribution of eggs and larvae after a certain period of transport. Including mortality functions in the model (either simple time functions or more complicated functions related to environmental factors) will enable an estimation of the absolute numbers of larvae per unit of time and space.

6 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

7 References

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Justification

Rapport C026/11
Project Number: 430.25015.01

The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

Approved: C.J.G. van Damme, MSc
Researcher

Signature:

Date: 5 March 2011

Approved: J. Asjes MSc
Head of Department

Signature:

Date: 8 March 2011

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